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A landscape scale model of thaw lake development and its implications for Arctic methane emission.

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Thawing of ice-rich permafrost in lowlands may create thaw lakes on a large scale. Many Arctic lowlands are covered with these thaw lakes, and drained lake basins. Also during the Pleistocene thaw lakes developed in the periglacial zone in Europe. Methane emission from thaw lakes is considered as a major source of methane, contributing to the Arctic global warming feedback.

To quantify this methane source, we developed a stochastic, landscape-scale model of thaw lake evolution. The model contains all key elements of the thaw lake life cycle: initiation by localized melting of ice-rich permafrost, lake expansion by bank erosion, lake drainage by contact with the drainage system, and re-growth of ground ice in drained lake basins. The model is able to reproduce the areal lake fraction, lake size and shape distribution of test areas in eastern Siberia.

We simulated the major lake development phase that created many lakes in Siberia at the transition of the Last Glacial to the Holocene. This generated a peak in lake area, which was subsequently reduced by widespread lake drainage. After this first peak, lake area oscillates in a stable climate at a lower equilibrium. These oscillations may be an intrinsic feature of the system.

By coupling the model to climate output we simulated the effects of future global warming for a test area in northeastern Siberia. In most simulations, the thaw lake area first grows, but is strongly reduced by frequent lake drainage after approximately 70 years.

In both simulations, lake area is strongly reduced by lake drainage, also if continuous permafrost persists. Extrapolating the simulated lake areas to methane emission, this results in an estimate for future methane emission from thaw lakes. Our estimate is an order of magnitude lower than previous estimates, based on complete thaw if ice-rich permafrost areas.